RADIO RECEPTION PROBLEMS

The Problem with Radio Reception in Commercial Structures

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Appendix E Not Included. Please visit the Learning Resource Center on the Web at http://www.lrc.dhs.gov/ to learn how to obtain this report in its entirety through Interlibrary Loan.

CERTIFICATION STATEMENT

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Abstract

The problem is that many Aurora Fire and Police employees believe that the recent communication problems were related to the abandonment of the digital system. The two recent incidents involved police officers unanswered request for assistance from inside commercial structures due to what they believed to be, system failure. The implementation of the new MACOM radio system with the intent to use the digital technology failed and both Aurora Fire and Police reverted back to an analog system. The purpose of this paper through descriptive research was to determine if the recent communication issues were related to the change.

The general differences between a digital and analog radio system relating to public safety were researched revealing the advantages to be more information flow, interoperability, and voice clarity. However the disadvantage was that background noise essentially renders the digital system unreliable when used in operational incidents. Representatives from neighboring departments in the Denver metro area were interviewed identifying their similar concerns with the digital technology.

Both recent incidents were analyzed revealing the true problem was the steel reinforced concrete walls used in building construction not the abandonment of a digital system. The interviews with neighboring departments identified issues with building construction and they are actively enforcing their city or district policy requiring amplification systems be installed in new and existing buildings to alleviate the radio reception problems in similar structures. This analysis produced a recommendation that the City of Aurora approach the organizations with high occupancy loads such as schools and malls mandating the installation of amplification systems based on safety to both public safety employees and the citizens of Aurora.

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Introduction

The purpose of this research paper is to determine if the migration from digital to analog radio communications had any detrimental effects to radio performance. In order to understand the purpose a brief historic view is required. In the year 2002 the City of Aurora purchased an Enhanced Digital Access Communications System (EDACS). This system is a high-performance, critical radio communications system. This system was available in a variety of frequency bands. Aurora chose an 800 MHZ frequency band because it would easily support interoperability in the Denver Metro Area. It would also accommodate future growth and expansion of the system for many years. It was the primary intent of all departments in the City of Aurora to operate with a digital radio system.

The new digital radio system became operational in late 2004. Immediately after implementation the fire personnel began to experience many problems with fireground communications. When background noise was present voices were often garbled to the point of being unreadable. The problems continued until the Aurora Fire Department (AFD) abandoned the digital system and returned to an analog communications. The Aurora Police Department (APD) remained on the digital system for another year before the problems became insurmountable which prompted their switch to an analog system.

The problem that recently surfaced is some radio transmissions from inside buildings go unheard during emergency operations. When a call for back up or help goes unheard the situation becomes critical and dangerous for emergency responders. Both Aurora police and firefighters have been in situations where critical transmissions were not copied. To clarify the severity of the issue, these transmissions were not heard because they were unmonitored, upon

transmitting the radio tones indicated that the signal could not reach the system. In short the personnel were cut off from all communications due lack of system integrity. Based on this information the fire and police personnel immediately focused on the migration from digital to the analog system as the primary cause of the problem.

The descriptive research method will be used to identify the difference between digital and analog communication performance in relations to the incidents that have occurred. The operational incidents will be analyzed in hopes of determining a cause. The incidents will be reviewed and the structures where the communication problem exists will be a focus for analysis.

The following research questions guided this study:

1. What are the differences between digital and analog radio system in general and in relation to public safety?
2. Are there any recommendations or regulations supporting either digital or analog communications for public safety specifically the fire service?
3. Were the recent communication problems caused by the switch from digital to analog or are there other factors involved?

Background and Significance

The City of Aurora, Colorado is a large city encompassing 158 square miles and home to over 308,000 citizens. The city employs a manager, city council, and a mayor. The fire chief for the Aurora Fire Department (AFD) receives direction from the city manager. According to city ordinance the AFD is tasked with providing fire protection and emergency medical services (EMS) to the populace. The current call volume is approximately 30,000 responses handled by 340 online firefighters. These responses are divided between 15 fire stations. Each station houses a paramedic engine which provides Advanced Life Support (ALS) response. Current

minimum staffing rules exist at 4 firefighters per apparatus with a minimum of one paramedic per Engine Company. Over 70% of the responses require interaction with a patient (Aurora, 2006a)

The City of aurora also employs over 800 uniformed police officers divided between 3 geographic districts. On a daily basis the Aurora Police Department (APD) has over 200 police officers covering the city. The police staffing requirement is 2 per thousand of population which is now included in the city charter. In 2007 The APD responds to over 150000 requests for service (Aurora, 2006a).

Both public safety service providers for the city are dispatched by the Aurora Dispatch Center. The center is under separate management but still resides under the city rule. The dispatch center employs over 30 people to cover two 12 hour shifts daily. In 2007 the dispatch center received over 185000 requests for service between the Aurora police and fire departments. The Aurora Dispatch Center only provides dispatching services for the city public safety departments.

Both police and fire personnel are dispatched with a Printrac Computer Aided Dispatch (CAD). The Printrac CAD was installed in 1998 and is still operational with minimal problems. In 2004 the city chose to replace their antiquated Motorola radio system. There were a number of reasons the city chose to replace the radio system. The increased developmental growth of the city brought many radio reception problems. Many of the newly developed areas were in shielded by rolling hills that blocked radio reception. The increased radio traffic brought on by an increasing call load produced many busy signals when radio transmissions were initiated. When looking at statistics the number of radio transmissions that were required for services in

1995 were approximately 800,000. In 2004 the annual radio transmissions reached 3 million (Aurora, 2006b).

Another problem the city was facing was their inability to communicate with neighboring agencies. Interoperability was becoming a priority and with the antiquated Motorola system interoperability was non existent or extremely cost prohibitive. Even if upgrades could be added the system coverage was still a significant issue for emergency responders. For these reasons the city chose to move to a new radio system

To identify the appropriate radio system for the city a committee was formed which included representatives from police, fire, communications, and the information technology departments. This committee researched many different systems and visited other municipalities in order to identify the appropriate radio system for the City of Aurora.

With much research the city chose to purchase the MACOM radio system with digital capabilities. The system was installed and operational in February 2004 and both police and fire were operating within a digital system. It wasn't long after the go live date when complaints began to accumulate. In late 2004 the AFD chose to eliminate all digital channels except the dispatch channel and resume operations using analog frequencies for all communications. The problems that AFD encountered with the digital system significantly impacted firefighter safety on the fire ground. The switch from digital to analog immediately resolved all communication issues. APD continued operations on the digital system until there problems became insurmountable in 2006, and then they migrated to analog which is where they currently operate.

Parallel to the radio project the AFD was researching and developing a process to monitor radio frequency coverage in new commercial structures. This project was preempted from the communication problems that occurred in 9 /11. It was based on the characteristics of

radio signals that they cannot penetrate steel and concrete. To help alleviate the problem of loss of communication in buildings, the City of Aurora implemented an ordinance in August of 2004 requiring all new commercial structures be tested for radio frequency coverage. If the buildings fail them the owner would be required to install a radio frequency amplification system enabling the radio transmissions of police and fire. There are parameters for the size of building that this ordinance applies. Based on the research conducted, the building size was set at a minimum of 50,000 Sq. Ft. (City of Aurora, 2004). This figure was consistent across the nation as to building size. Based on MACOM recommendations the frequency minimum was set at -88 dB. Once the ordinance was designed and signed into law, the process to enforce this requirement was implemented. In mid year 2005 the city was enforcing the radio frequency requirement for all new construction. Reports indicating radio coverage had to be provided prior to receiving a certificate of occupancy (CO) and if a system was required the install had to also be completed prior to issuance of a CO. Currently the city has 22 commercial structures that required an amplification system to improve radio reception in the core of the structures.

The final item of importance that impacts this research paper is the recent incidents that have occurred. The first issue brought to the attention of the Information Technology department was the radio dead spots in a high school that was constructed in early 2004. This high school, Cherokee Trail, is a large school, over 100,000 sq. ft. Since the permit was issued prior to the ordinance requirement the school was not required to provide radio frequency coverage. Numerous complaints were submitted indicating that both radios and cell phones were inoperable within the structure. A police officer requesting assistance from the men's locker room went unanswered because the radio indicated a system inaccessible. (Appendix A)

The second issue was also reported by the APD. In the Aurora Town Center, a large shopping mall, again constructed prior to the ordinance, was the site of the most recent issue. A police officers call for backup went unanswered when he had a perpetrator at gunpoint. The officer was in a store named Hollister's that was adjacent to Dillard's an anchor store on the East side of the mall. (Appendix F) The request for help was not heard because there was no reception in this area of the mall. This specific incident produced media attention. These two incidents prompted a renewed interest in the performance of the radio system

As reported earlier in this section both police and fire abandoned the digital system and moved to analog. This move was prompted by years of problems, battles, and media focus between the vendor, police, fire, and the internal technology department. Based on past history and the recent incidents, the migration from digital to analog communications is now being tagged as the primary cause of all performance issues.

Therefore the impetus behind this research paper is to determine if the change from digital to analog could have been a major contributor to the radio issues.

The Executive Leadership Class focused on a number of items that relate to this paper. Managing change in the fire service is a delicate process and even when the change is successful without issue, acceptance is often a slow transition. When significant problems are encountered such as this project, acceptance may never be an option. However, when dealing with a critical infrastructure need which in this case is communication, there has to be a level of trust with the equipment and process that is used daily by all personnel. This project has challenged the management staff of fire, police, and city administration because the implementation process was long and problematic. As a fire officer and an EFO participant it is paramount that the rank and file has a high degree of trust in the individuals that make the decisions impacting their lives.

The general feeling is that the city settled for an inferior system with no regard for the fire and police safety. Whatever the outcome this research paper will give us a better understanding and a high degree of knowledge which will enable us to either educate all personnel as to the effectiveness and/or the ineffectiveness of the radio system. This information will guide us to making decisions in the future for the safety and consideration of all.

Literature Review

The first question is what are the differences between a digital and analog radio system in general and in relation to the fire service? With the given history, switching from digital to analog requires that the performance of both systems be researched. According to MACOM a digital system has one fundamental advantage over traditional analog systems. The transfer of information is with mathematical precision. For this reason the digital modulation is much more reliable and forgiving for data. The second advantage identified by the committee was the ability to expand the system to handle a significant amount of growth. The third advantage identified by the police representatives was the ability to encrypt any and all radio frequencies. (Jones, 2007)

Based on information from the Federal Communications Commission (FCC) Digital radio systems offer many advantages over the traditional analog radio. Among those are better audio quality, stronger signals, and multiple channels. Another primary advantage is that digital systems are capable of transmitting much more information in the forms of voice or data. The technical term for this is “increased bandwidth”. (Federal Communications Commission, 2007)

With one of the primary advantages being stronger signals, the research needs to focus on the advantages of this strength for public safety. Converting from analog to digital increases coverage in areas where the topography can be a significant problem. A specific example is the

Country of Australia. They currently switched their radio and television transmissions to digital. The digital system was able to overcome the primary problems associated with the topography of the country and the sparsely populated remote areas. (Digital Radio Australia, 2007) A similar concern for public safety providers is the ability to transmit and receive radio transmissions from remote areas within their individual response jurisdictions.

Another issue surfaces with the switch to digital is the transition period in which analog communications will be eliminated. The most recent example is in the United States in February of 2008 the analog televisions that were still in use became nonfunctional because of the switch to digital signal transmissions. Prior to this date most television stations broadcast in both analog and digital thereby enabling anyone with an antiquated TV the ability to view digital television broadcasts. (Oregon, 2008)

For public safety there are other factors that must be considered. A primary factor for fire departments is background noise. As referenced by Imel and Hart, the difference between digital and analog is that digital modulation has one fundamental advantage, it conveys information by changing the voice and background sounds to data and then transmits this data. Unfortunately, the benefits end there, once digital converts the data to voice there are problems. Digital modulation precludes the ability of the human brain to decipher sounds such as speech and engine noise. Recognition of multiple sounds is difficult if not impossible when the signal-to-noise ratio of a digitally modulated signal falls below a certain threshold. With analog modulation, the human ear and brain can understand the speech that is buried beneath noise levels that digital circuits cannot deliver appropriately. (Imel and Hart, 2006a) Phoenix Fire recently implemented a new radio system and their report references issues experienced by New York Fire so they conducted tests which identified the same issues. The communication issues

were significant enough to continue the analog communications on the fireground. They currently conduct operations in this manner. (Worrell and MacFarlane, 2004)

Another significant factor for the fire service is radio signal building penetration. According to Kapsales narrow band digital radio communications provides a distinct advantage in building penetration when using a digital system, (Kapsales, 2004) However, Imel states that the only difference is the type of building construction and the digital/analog has no bearing on signal delivery within a structure. Only frequency bands have an effect on building penetration. (Imel and Hart, 2004b) The National Fire Protection Agency (NFPA) recommends that all operational incidents take place on a simplex system which is primarily analog and the reason stated is there is more building penetration. NFPA also recommends that all initial dispatching should exist on a digital system. (NFPA, 1221a)

An additional design feature difference between digital and analog needs to be identified. Earlier it was described that the digital transmissions are essentially sounds that are transferred into data transmission with mathematical precision. When the data transfer occurs the signals take very little space and therefore many transmissions can occur simultaneously without overburdening a system. This is a definite advantage for a large multiple agency incident. The digital system can handle many more transmissions than the conventional analog. Thus the migration to digital is a plus for interoperability and highly used systems. Essentially radio systems are governed by voltage so based on that fact, analog transmissions take slightly more voltage then digital therefore less voice or data can be sent through an analog path.

The second question, are there any recommendations or regulations supporting either digital or analog communications for public safety specifically the fire service? The NFPA has

long been the organization that has established standards for the fire service and associated partners in the business. Therefore NFPA is an excellent source of researched recommendations. The NFPA states that all dispatching of incidents should occur on a digital system. (NFPA, 1221b) Within the same section the recommendation is that all fireground operations occur on a simplex channel. This new term simplex will require a definition. Simplex channels are analog in nature and are not required to use a repeater. An example would be like the simple walkie/talkie's that were used for point to point communications. Simplex radio is the original, genuine, two-way radio. Simplex radio uses the same frequency for both transmit and receive. Today, simplex radio is primarily used for applications that need to go beyond "line-of-sight". Simplex radio is also used for aviation and marine applications where repeaters would not be practical. (Swift, 2009)

In the definition of simplex another term was used, repeater. A repeater in most cases is a radio with a tower on a geographical high point in which the radio signals pass through. Repeaters are used to overcome topography. If radio transmissions from a low valley can reach the repeater then the signal can pass through to any other radio that is in the system as long as that radio contains the same frequencies. (Wikipedia, 2008) A simplex system will not require a repeater and therefore can only transmit as far as the power input will enable or the topography will allow.

The NFPA states that the reason to use simplex channels for fireground operations is that there is less chance of interference and better building penetration. (NFPA,1221c). However, NFPA also recommends is to have every transmission recorded and therefore simplex channels require some sort of recording device on the fireground because these channels often never reach

a communications center. Darling in *Mission Critical Magazine* states the only improvement to building penetration is increased signal strength or some sort of amplification system within the structure. (Darling, 2006)

The third and final question asks if the recent communication issues could have been caused by the digital to analog change. The problems occurred within large structures. The first incident occurred inside a newer high school in the City of Aurora. Patrol officers located at the school were cutoff from communications. Several attempts were made to contact dispatch without success. The officers were located inside the school in the locker room area. (Appendix A) There were other areas where radio communications were questionable but not to the degree the officers experienced in the locker room area. The radios went into a "cc scan mode" which indicates the radio cannot reach a tower or receive feedback. (Tyco, 2004)

Currently APD believes all the communication issues are directly related to the migration, while others, city management, suspect the building construction to be the problem. This high school is constructed with steel and concrete and according to Phoenix Fire this type of construction is often impervious to radio communications. (Worrell and MacFarlane, 2004) Additionally the FCC has numerous articles indicating the how problematic this type of construction has been on not only radios but cell phones. The issues are the same, signal strength. (FCC, 2008)

The Aurora Town Center, the site of the second issue is somewhat similar. The police officer requesting backup went unheard due to signal integrity. This individual was inside a store within the mall. (Appendix F) Again the research indicates that construction plays a huge role in signal transmissions. According to *Critical Mission Magazine* the problems are being overcome

with amplification systems installed in the structures so that the coverage is consistent inside of a structure. (Darling, 2006)

Procedures

The purpose of this research paper was to determine if the migration from digital to analog communication exacerbated the recent communication incidents. To replicate this study the first step would be to research each incident to determine the cause. With the cause determined the next step is to contact other jurisdictions to see if they have experienced the same type of communication issues. With the comparison completed the answer as to whether digital or analog communications had an impact should be identified.

The Denver Metro Area is an excellent place to conduct this research and interviews. Currently there are two major communication systems in the Metro Area. The cities of Aurora, Denver, and West Metro Fire Protection District use the MACOM system. Most of the others which include Parker Fire, South Metro Fire, Cunningham Fire, and Littleton, operate on the State system which is Motorola. This information is important because there is one significant difference in the systems and it is the primary focus of this research paper. As stated earlier the City of Aurora migrated from digital to analog due to performance. The option was not available in the State system. If the City would have purchased the State system the option to revert back to an analog system would not have been available. The committee tasked with choosing the radio system for Aurora considered this point an advantage.

The first step in determining the cause is to replicate the incidents so there is subject matter to evaluate. The first incident occurred in the Cherokee Trail High School. A resource officer, a member of the APD, called for help in a situation where backup was needed. The call

came from the men's locker room area. The school map in the appendix (Appendix A) indicates the exact location of the call. To determine if the call went unanswered the incident was reenacted. Both APD and AFD radios were used. The first call from the same location produced a (CCscan) identifier in the portable LED display. This code indicates there is no reception. This process was used with both APD and AFD radio with the same results. The channel used was TAC2 for fire and TAC 21 for police. Both these channels are used for operational incidents for each organization and they are both analog in nature. A second attempt was made using the "Dispatch Channel" which is the only channel that remained digital on both systems. The dispatch channel is used to dispatch personnel to an incident. In the verbal of the dispatch process AFD and APD personnel are advised which TAC channel will be used for the operation. The responding individuals will then switch to the TAC channel to complete the incident. For this test the dispatch channel was used to test the digital system. Both transmissions from the radios produced a (CCscan) in the LED display again indicating that there was no signal reception.

The testing continued in numerous areas of the school. The map in the appendix (Appendix B) indicates the areas of testing and the transmission results. The same process was used at each site. First the transmissions were made on a TAC Channel then on the dispatch channel. There are a variety of results. Where the communications could be heard we rated the communications for volume and clarity with a rating scale from 1-5. (Appendix C) This scale was a standard rating scale used but the Aurora Dispatch Center when evaluating radio transmissions. Due to the number of results produced by the testing the next step was identified.

Since the testing did not produce the same results throughout the building the next step would be to check the signal strength inside and outside the building. To test the interior the same map of Cherokee Trail High School was used. A MACOM portable radio programmed to read frequency strength was used to test the structure. The frequency readings are in decibels a standard measurement in the communication field. The readings were acquired in the same manner as the City ordinance indicates for radio frequency testing. (Aurora, 2005) The City of Aurora Information Technology, Police, and Fire Departments were used to test the school. The ordinance indicates that the structure be divided into square sections and each section receives a frequency strength reading. The building is required to have a frequency reading of <-88 dB in 90% of the structure. Additionally there can be no adjacent sections with noncompliant readings. The dB (Decibel) is a measurement indicating the electrical power of the transmission. Typically in the MACOM network acceptable signal strength is between (-20dB and -88dB). However, total signal failure will be encountered at levels of (-111dB). A total failure of the transmission is detected by the user when the LED screen in the mobile or portable radio indicates "CCscan" and no contact can be made with either dispatch or listening party. Audible transmissions between (-88dB and -109dB) can exhibit several deficiencies. Among those may be low volume, distorted messages, and patchy voice signals. (Tyco, 2004b)

Often the question arises as to why the frequency level was set at -88db. This reading comes as a recommendation from the vendor, MACOM. It is based on the signal strength that is present in the city, the number of radio towers in the system, and the variables which public safety personnel may encounter. These variables may be remote microphones, antenna location, battery power, and proximity to interfering structures or other items. All issues mentioned have a negative affect on the ability to receive a signal. All the tests were conducted with standard

portable and mobile radios absent of remote microphones with the antenna in a perpendicular position to the ground. This afforded the best possible signal. The results are indicated in the appendix and summarized in the results section. (Appendix B) The final step in the testing process was to walk the exterior of the structure and take readings from all sides. This process was used to determine the exterior signal strength in relation to the radio tower locations. A map of the school and the towers are in the appendix. (Appendix D)

The next incident identified in the background section occurred in the Aurora Town Center. This center is a shopping mall constructed in the early 80's. Since the construction was prior to 2004 the radio frequency ordinance did not apply. The incident occurred in the lower level approximately 50' inside the Hollister's store almost adjacent to Dillards. The police officer had a perpetrator at gunpoint and was calling for help via the radio. The cry for assistance went unanswered when the (CCscan) appeared in the LED window and the alert tone indicated no signal. The police officer was able to move approximately 10 feet towards the entrance where he then was able to reach the dispatch with a radio transmission requesting help.

To determine the cause a similar process was used. The first step was to again take AFD and APD radios and test both the TAC and dispatch channels. This again would test both the analog and digital system. The testing produced comparable results. The results are indicated in the appendix section. (Appendix, E) However due to the size of the mall the city was not capable of testing the complex. To identify the radio frequency strength in the mall Advanced Communications was contracted to survey the Aurora Town Center. The document in the appendix identifies the signal strength in the mall proper and does not include the four anchor

stores JC Penney, Macy's, Dillards, and Sears. The final step included testing the radio frequency strength on the exterior of the structure. (Appendix G)

There were a number of limitations encountered in this research project. Since the incidents occurred with on duty officer radios, that condition of their individual radios could not compared. Other items are the attachments that were on the radios. MACOM indicates there is a 10 dB loss in signal when a remote microphone is attached. At this time 95% of the police and fire officers use remote microphones. Both officers were using remote mikes. The other factor is radio location. MACOM again indicates that there is at least a 5 dB loss in signal reception when the radio is attached close to the belt line. Another item of concern was the battery condition of the officer's radios. This was not duplicated for the testing process because this information was not available. Low batteries have a disastrous effect on the performance of the radios. Our tests were conducted without remote microphones and with batteries in good condition. The radio signal strength was rated with the radios at face level perpendicular to the ground. This is the optimal position for greatest performance.

On other limitation should be noted. Since the maps of the city cannot indicate elevation it should be identified that the Cherokee Trail High School sits low in a valley and is almost shielded by terrain. This is not the case for the Aurora Mall.

To acquire information from the metro Denver area, six agency representatives were asked three specific questions relating to digital and analog communications, and reception in buildings. The three questions:

1. What communications occur on a digital system and why?

2. What communications occur on an analog system and why?
3. When communicating from inside of structures is there a preference as to digital or analog for reception performance?

The agencies interviewed were, Denver Fire Department/ Lineman Craig Sheerer, Cunningham Fire Department / Division Chief David Markham, Parker Fire department / Firefighter Jeff Tyler, South Metro Fire Department / Jeff Tyler, West Metro Fire Department / Captain Landis, Littleton Fire Department / Captain Randy Glanville.

These agencies were specifically chosen because they represent a variety of operational systems. Denver and West Metro Fire Departments operate with a MACOM radio system and both currently have city ordinances mandating radio frequency coverage in large square footage structures. Cunningham, South Metro, Parker, and Littleton Fire operate on the Motorola System and also maintain radio frequency ordinances for large buildings. Remember that the later agencies are not able to operate on analog channels as stated earlier in this document.

The purpose of these interviews was twofold. First was to determine if their process was similar to Aurora and second was to determine if their experiences were similar in nature to Aurora's. Therefore the information leads to the credibility of the document.

Results

The first question regarding the differences between digital and analog radio systems in relation to the public safety was answered in both the literature review and procedures section. There are significant differences between the systems with the first difference being transmission characteristics. As you reach the threshold where the radios almost fail the differences become

obvious. At this failing point the digital communication can no longer be understood and is just patchy sounds. With an analog system you will encounter static until the signal cannot be understood. The testing indicated that both the digital and analog signals failed but consistently you could copy the transmission more often in the analog system. Although the digital produced sounds the message could not be understood. When the radios reached a (CCscan) mode there was nothing but radio silence. This (CCscan) threshold was sporadically encountered a levels between – 109 and -111 dB but consistently at -112 and lower.

Another major difference is the amount of information that can be carried through an analog system as compared to digital. Since digital signals are compressed mathematical data several transmissions can be carried through one pathway and then disseminated to the individual receiver. This process is also available for data. In the analog system voice is carried though wave forms similar to digital but the number of wave paths carried through a path is limited. For data transmissions a conversion is required to so this process takes space and time and therefore the amount of data is limited. Both systems are governed by voltage and the analog system requires more voltage to send the same number of signals whether voice or data hence the reason digital can handle more radio transmissions. This is truly an advantage in an incident where channels are limited or there are so many operations occurring simultaneously requiring multiple conversations. This would be an event covering a broad area with multiple jurisdictions involved. In short the very large scale incidents would struggle in a total analog system because the analog system would be overwhelmed prior to the digital.

The next item is building penetration. As the tests indicated in (Appendix B) there is no difference in signal strength between the digital and analog system. This was repeatedly the outcome for every testing point at Cherokee Trail, the radio was switched from the dispatch

channel where a reading was taken then to the analog channel where the next reading was taken at the exact spot and the signal strength range did not change. Another significant item of importance was that the outside signal strength and radio transmissions were all successful whereas directly behind concrete and steel the signal strength lessened and the voice transmissions became weak or lost in areas that exceeded the operating threshold of -109 dB. Based on the procedural testing the only difference between digital and analog strength regarding building penetration is the transmission characteristics that were mentioned earlier in this section.

The second question asks if there are any regulations or recommendations indicating the use of digital or analog communication within public safety specifically the fire service. The results were derived from the literature review section and interviews with the neighboring districts. Currently the NFPA indicates that the dispatching process should occur on a digital channel and fireground operations should migrate to a simplex channels so as not to over burden the system. In the Metro area this presents a number of problems. The simplex channels are analog but they will not pass through a repeater. Therefore the recording of communications is not possible unless an on site recorder is used. Recording of all information is a requirement as stated in NPFA 1221. To further define “all information”, it includes radio transmissions, data transmissions and messaging via text or verbal between dispatchers. This is emphasized by the Insurance Services Organization (ISO) who rates each city for fire protection. The ISO will firmly state NFPA 1221 requires the recording capability within a dispatch center. This presents ambiguity between the NFPA requirement and the current ability of the radio systems in the Metro Area.

The interviews produced interesting results on question number two. Currently all agencies dispatch on a digital channel. Cunningham, South Metro, Parker, and Littleton stay on digital tactical channels until their incidents involve three or more pieces of apparatus or include more apparatus from a neighboring district. A typical medical incident will include an engine company and a transport unit. This type of incident will be conducted on a digital channel. When asked why, the agencies state that the digital is dependable for incidents where there is minimal transmissions and background noise. Currently over 75% of the emergency responses in the city of Aurora are medical in nature or only require a single unit response, so it is an assumption that the data from these departments are similar. (Aurora, 2007) When more apparatus respond such as a structure fire, Cunningham, South Metro, Parker, and Littleton will move to an analog or a simplex channel so that their radio transmissions are understood. The primary reason is that the background noise significantly hinders the radio transmissions on the digital system. Background noise does not hinder the simplex or analog channels. This information is supported in the literature review where it is stated that the digital system is a mathematical data transfer and the analog signals are oriented to the human senses. When transferring one data set such as voice the digital system has minimal problems. When transferring voice and diesel background noise the human ear in conjunction with the brain has difficulty understanding the transmissions.

However Denver and West Metro Fire Departments conduct radio business similar to the City of Aurora. They as do Aurora, dispatch on a digital channel and then immediately migrate to the assigned tactical channel which is analog. The reasons are the same as the previously mentioned departments. However there is a significant difference in the radio systems. When these departments switch to an analog channel, all transmissions are routed through their

repeaters so all communications can be monitored and/or recorded through the dispatch center. Both Denver and West Metro have chosen to keep all tactical operational channels analog in nature. When asked why, the answer is quality of the radio transmissions. As stated earlier this is the reason that Aurora migrated from a digital to analog system.

Another point needs to be presented and it is related to the NFPA requirement. During the interviews it was apparent that all organizations would like to have all radio transmissions monitored by the dispatch center. Currently South Metro, Parker, Cunningham, and Littleton migrate to a simplex channel when working a structure fire. When they use these channels all radio communications go unmonitored by a dispatch center. The impression received is that these departments would like to have all transmissions monitored. However they chose transmission clarity over monitored. Denver, West Metro, and Aurora all dedicate a dispatcher to monitor the tactical channels.

Question number three, were the communication issues caused by the migration from digital to analog, is answered in the literature review, and firmly supported in the procedures section. The primary difference between digital and analog is the characteristics of the transmissions. The incidents occurred inside structures where the indicated signal strength hinders or eliminates the ability to communicate through a radio system whether the system is digital or analog. This is reinforced by the signal strength readings in these areas. As the attachments indicate the areas where the incidents occurred are essentially radio dead. Yet as indicated in the background section, movement approximately 10 to 20 feet in either direction could provide enough signal strength to complete the radio transmission. Both structures are constructed in a similar manner in that the exterior walls are steel reinforced concrete. In Cherokee Trail High School the walls are lined with metal lockers. In the Aurora Mall the actual

separation is two steel reinforced concrete walls. The data indicates that in perfect testing conditions the signal strength in the two separate areas would not support any communication effort.

To summarize, there are differences between digital and analog systems. The primary advantage in maintaining a digital system is the increased amount of voice and data transmissions over an analog system. However, given the current performance of the digital system the advantage may be limited.

The regulations and or recommendations at this time are somewhat ambiguous for the Metro area, given their current radio capability. Total compliance with NFPA 1221 would be difficult. This is based on the NFPA recommendation to move to a simplex channel when operating on the fireground. In another section it is required that all communications be recorded which in the Metro area is possible but it would have to be covered with an on scene recording device.

Based on the data from the literature review and the testing process identified in the procedures section the migration from digital to analog had no effect on the radio transmission issues.

Discussion / Implications

The results produced some interesting information. Aurora City management believes that the radio system is dependable and trustworthy. Initially I believed we settled for a product that was less then what was expected. And to some degree I believe we did. However based on the researched information it appears as though AFD has adapted to a changing environment by utilizing the best features of both systems. My beliefs were substantiated when the interviews

were completed. Other departments would like to operate in the same manner but limited in their options. I did not realize this until this research was completed.

The problems that were encountered by the APD would have occurred in any system. It is based on building construction, you cannot communicate from a vault and both the structures were similar. Steel reinforced concrete walls block radio penetration. All the data supports this belief. Whether the system is totally digital or analog there is very little difference in the performance inside structures. This research paper does significantly support the radio frequency ordinance that is currently in place. If the structures fell under this ordinance I can say with a high degree of certainty that the radio issues would not have occurred.

With question number two, the regulations and recommendations, based on the research and interviews, I believe the NFPA was premature in their recommendations. The NFPA has been the leader in establishing standards for the fire service but in this case the recommendation that digital communications be the primary communication process has presented some problems in the metro area. However this belief may be isolated to the metro area because my research focused on this area. It may be different in other areas of the country. I do agree that if digital communications could overcome the issues that one consistent system would be a great advantage nationwide.

Question number three is answered in the data that was produced in the procedures section. The problem is still present, based on the incidents that occurred both AFD and APD are suspicious of the current radio system. The Executive Fire Officer program specifically the Executive Leadership class emphasizes the importance of integrity as a leader. The class also emphasizes that a primary role of leader is to effectively manage change. Both these items are

in jeopardy when you as a leader are presented with the question as to why you are supporting a system so critical to the operational safety when you should be fighting for immediate change. This statement is how this research paper directly relates to the Executive Leadership course.

Recommendations

The recommendations that come from this research paper are that the City of Aurora continually monitor new construction and enforce the radio frequency requirement. In the ordinance specifically stated, the fire chief has the authority to label a structure a special hazard and therefore can mandate that they comply with the ordinance even though the building was constructed prior to the adopted ordinance date of August 2004. The specific recommendation would be to mandate the schools and the high occupancy areas such as malls to comply with the ordinance.

The final recommendation is to disseminate this information to all personnel in an acceptable manner in the hopes that it will help to overcome the insecurity of the radio system.

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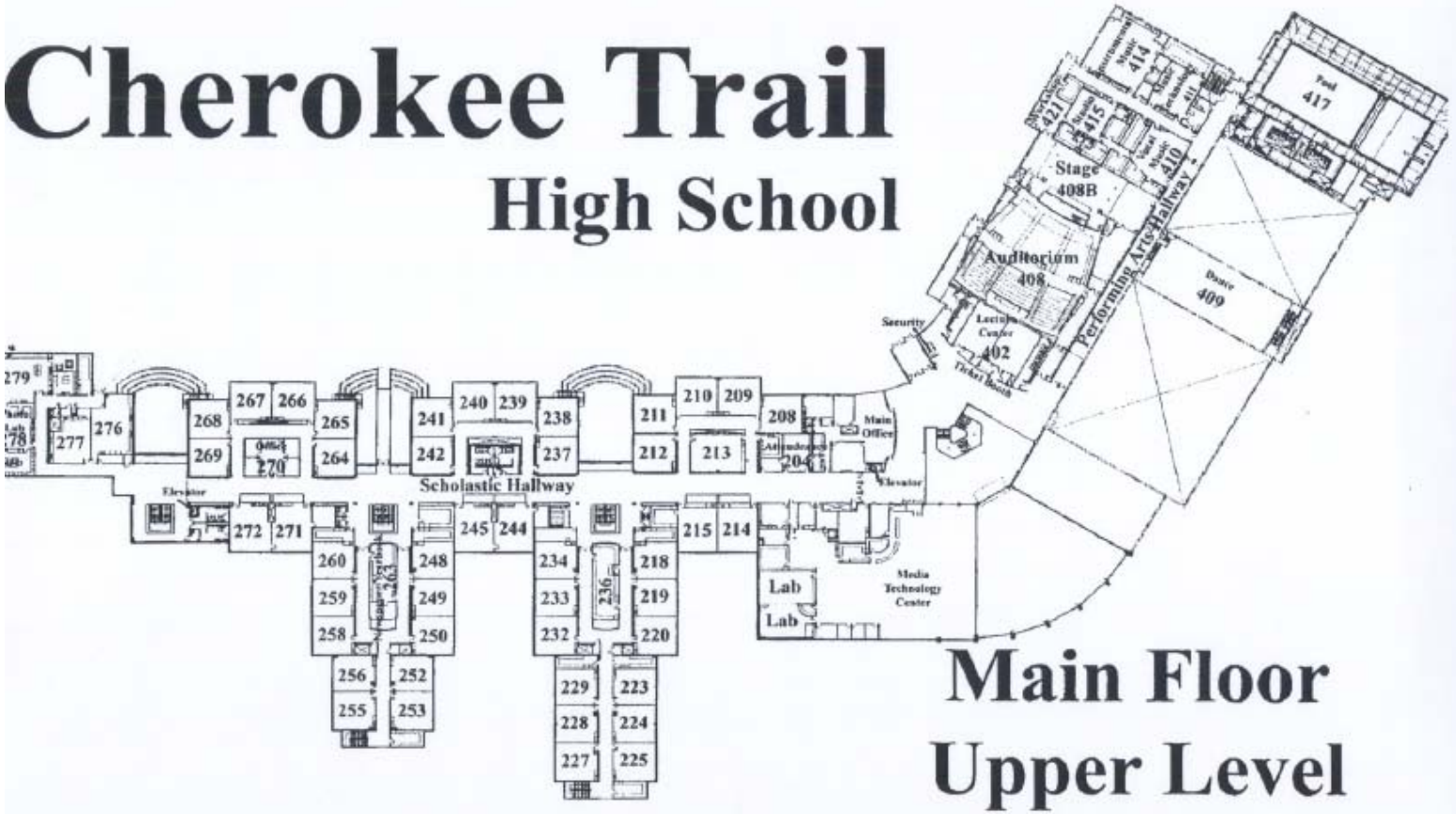
Cherokee Trail

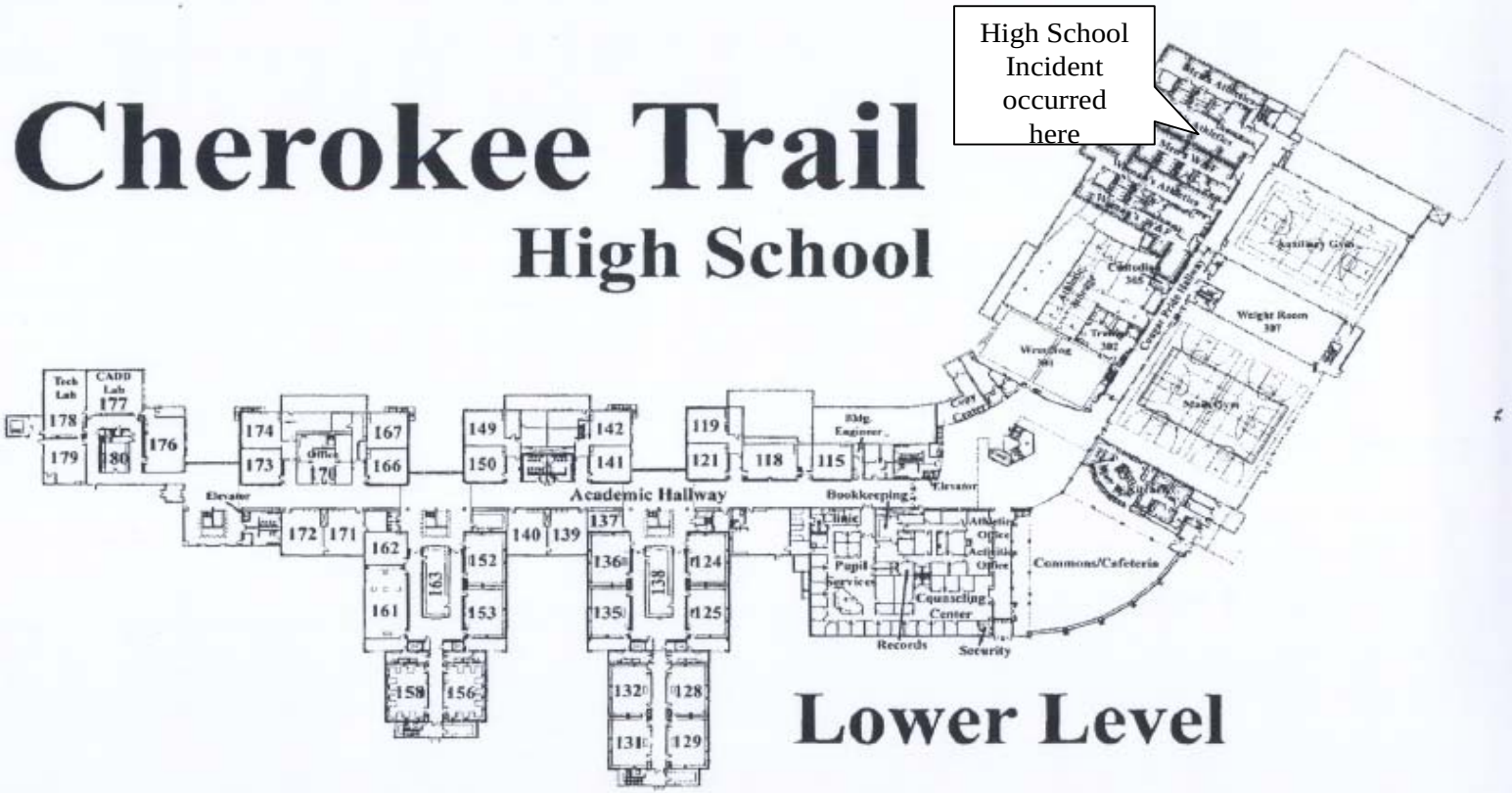
High School



Main Floor

Upper Level

Cherokee Trail
High School

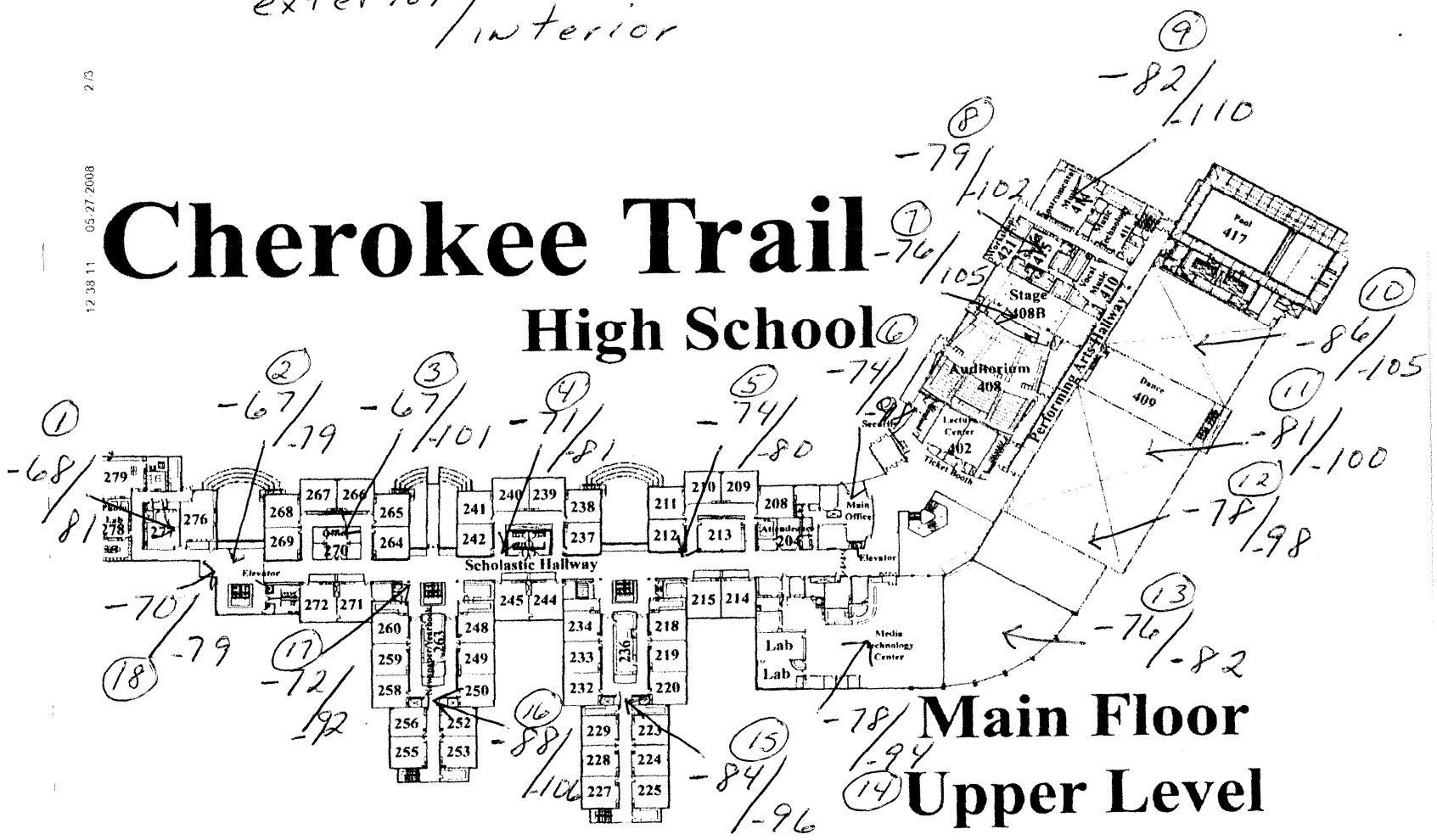


Lower Level

exterior / interior

Cherokee Trail

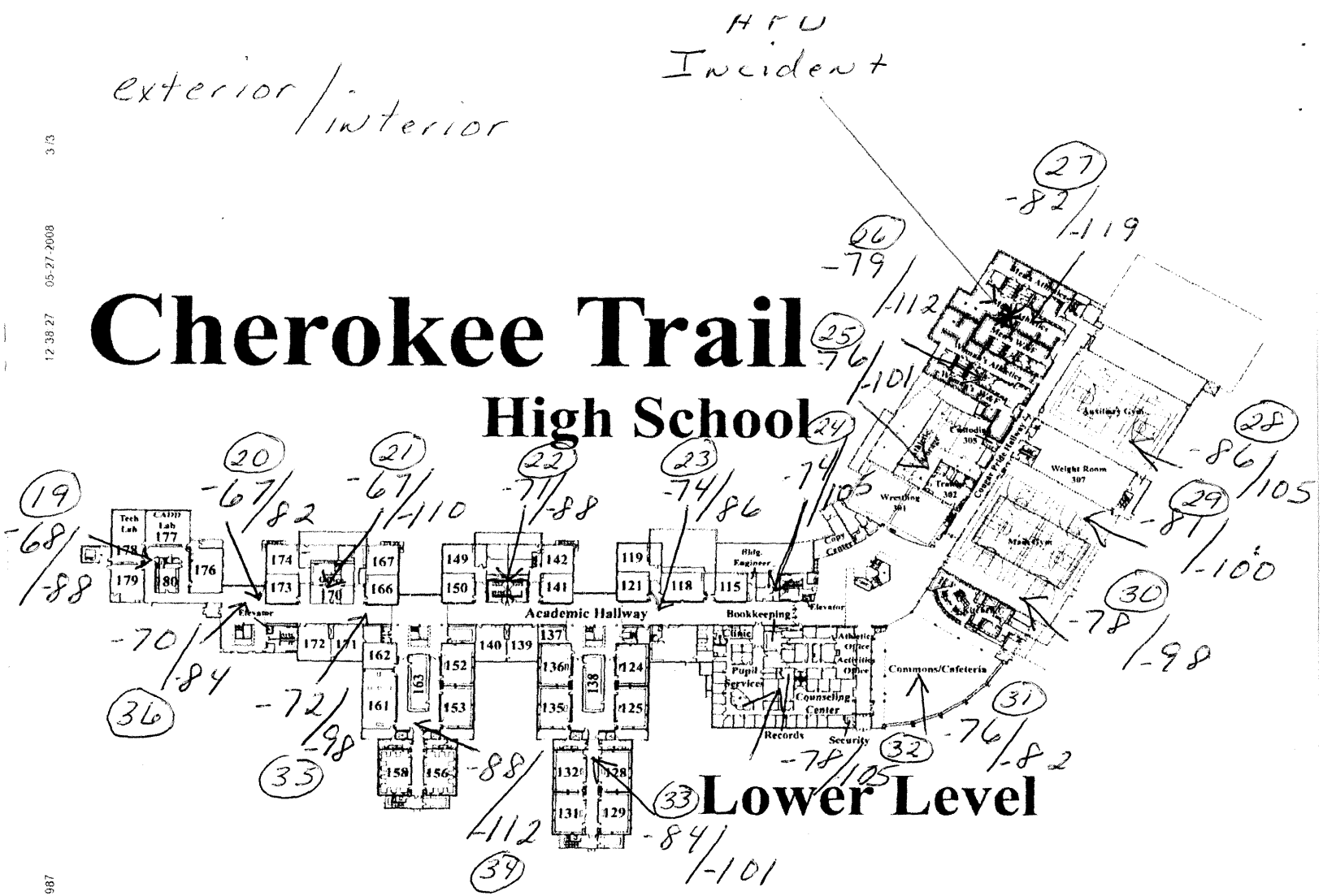
High School



-68/81 -67/-79 -67/-101 -71/-81 -74/-80 -74/-98 -79/-102 -82/-110 -76/-105 -86/-105 -81/-100 -78/-98 -76/-82 -78/-94 -84/-96 -88/-100 -72/-92 -79 -70

Main Floor

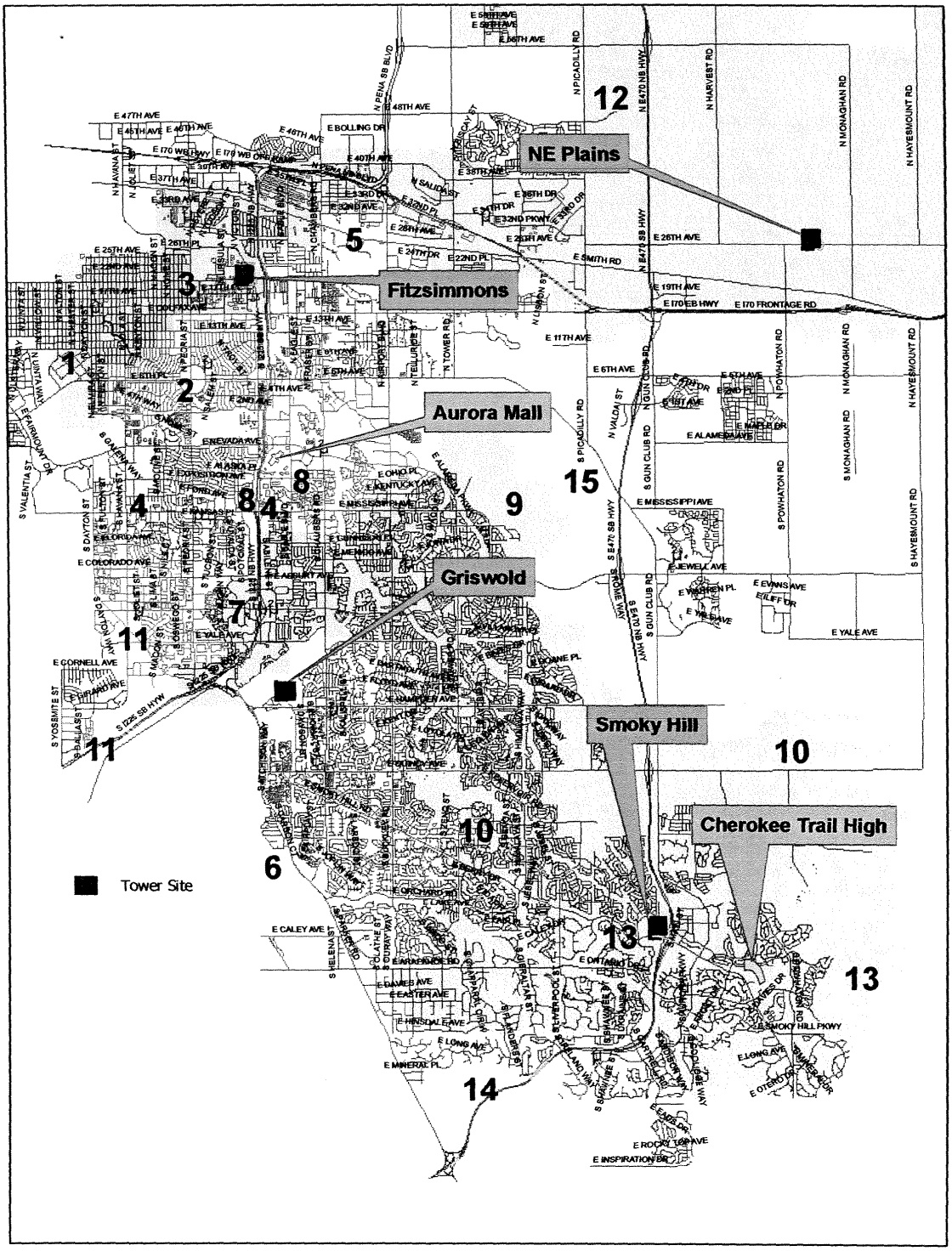
Upper Level

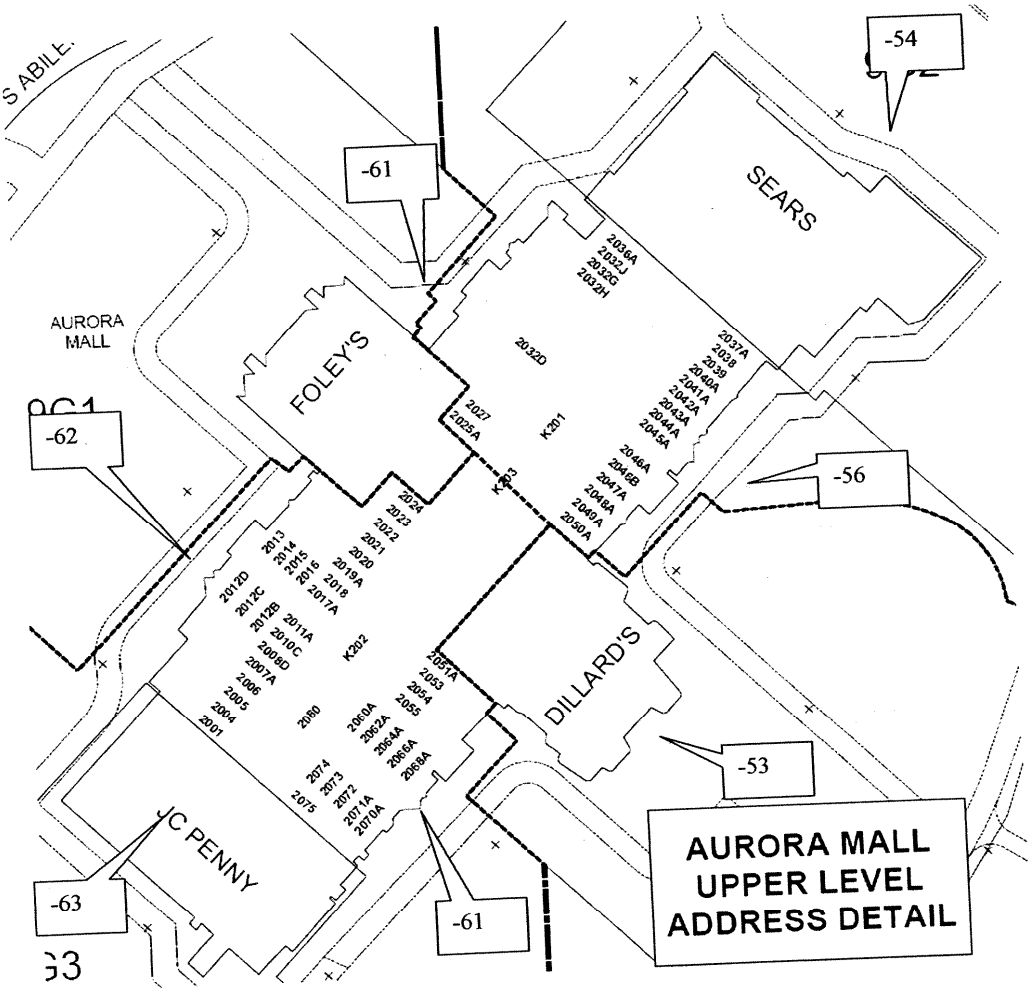


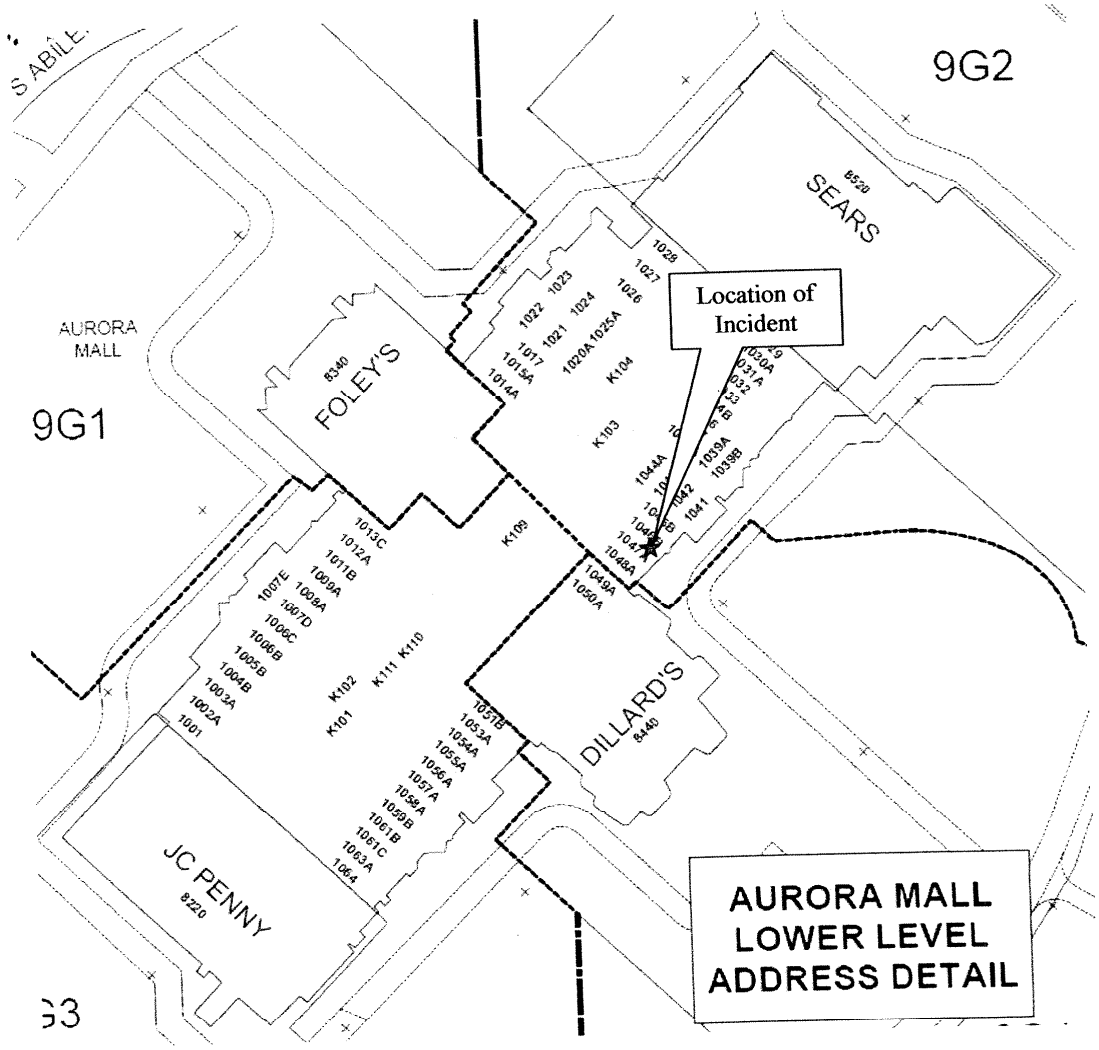
Cherokee Trail Radio Frequency Evaluation				
Area	Exterior	Transmisson Rating Exterior	Interior	Transmisson Rating Interior
1	68	1	81	1
2	67	1	79	1
3	67	1	101	3
4	71	1	81	1
5	74	1	80	1
6	74	1	98	2
7	76	1	105	3
8	79	1	102	3
9	82	1	110	4
10	86	1	105	3
11	81	1	100	3
12	78	1	98	1
13	76	1	82	1
14	78	1	94	1
15	84	1	96	1
16	88	1	106	2
17	72	1	92	1
18	70	1	79	1
19	68	1	88	1
20	67	1	82	1
21	67	1	110	3
22	71	1	88	1
23	74	1	86	1
24	74	1	105	2
25	76	1	101	2
26	79	1	112	CC scan
27	82	1	119	CC scan
28	86	1	105	3
29	81	1	100	3
30	78	1	98	1
31	76	1	82	1
32	78	1	105	3
33	84	1	101	3
34	88	1	112	CC scan
35	72	1	98	1
36	70	1	84	1

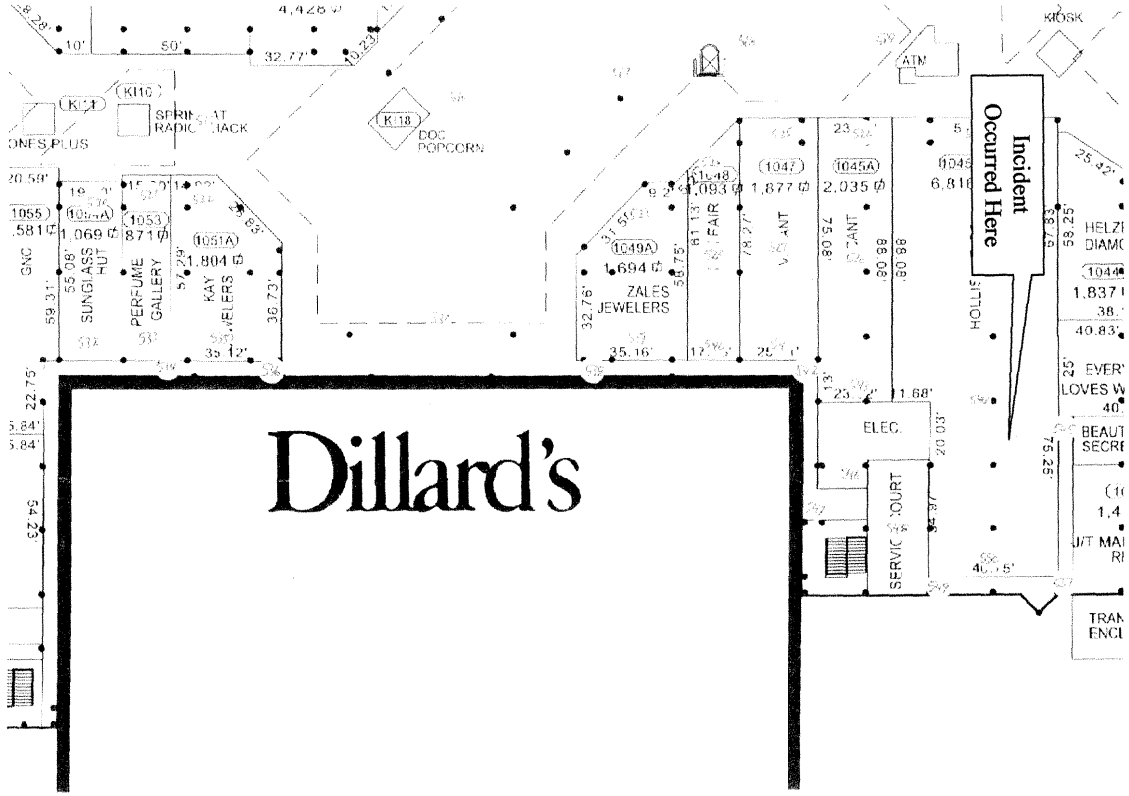
Radio Transmission Rating Scale

1	Clear and precise communication
2	Slight distortion good volume and readable
3	Slight distortion lower volume then normal
4	Significant distortion or distant low volume
5	No communication


NE Plains
Fitzsimmons
Aurora Mall
Griswold
Smoky Hill
Cherokee Trail High
Tower Site
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15


-54
-61
SEARS
AURORA MALL
FOLEY'S
-62
-56
DILLARD'S
-53
JC PENNY
-63
-61
AURORA MALL
UPPER LEVEL
ADDRESS DETAIL


9G2
SEARS
8520
Location of Incident
AURORA MALL
9G1
FOLEY'S
8340
DILLARD'S
8440
JC PENNY
8220
AURORA MALL
LOWER LEVEL
ADDRESS DETAIL


Incident Occurred Here
Dillard's
ATM
KIOSK
DOG POPCORN
SUNGLASS HUT
PERFUME GALLERY
KAY JEWELERS
ZALES JEWELERS
FAIR
VACANT
ELEC.
HOLLIS
1,069 ☐
871 ☐
1,804 ☐
1,694 ☐
1,093 ☐
1,877 ☐
2,035 ☐
6,816